Arduino Nixie Clock v6

Operating Instructions

Description

The Arduino Nixie Clock is a beautiful mix of old and new, resulting in a high accuracy, low power clock which will be a talking point in your home.

The clock has the following features:

- Battery backed, temperature compensated, high accuracy clock. The accuracy is Accuracy ±2ppm from 0°C to +40°C. (Maximum 1 minute per year).
- The battery life should be 3 years in normal use.
- Retains the date and time even when turned off (not just for a few minutes, but for as long as the battery lasts)
- Leap Year Compensation Valid Up to the year 2100
- Based on the Arduino micro-controller: Easy to program an well documented.
- Open source hardware and software. Nothing is hidden in this clock.
- You may modify and load the software with a normal PC
- Low power consumption.
- Anti Cathode Poisoning (ACP) makes sure that the tubes will stay healthy for many years with no intervention from you.
- All settings are stored in non-volatile memory. Once they are set, they are remembered forever, or until you change them again.
- RGB back lighting allows you to set the the color of the back lighting to practically any color you desire.
- Ambient light sensing, with automatic tube dimming, which sets the tube and LED brightness according to the light conditions. The tubes could be disturbing during the night if they are left at full brightness.
- Absolutely silent operation. Some Nixie clocks emit an irritating “buzz” or “hiss” which is especially annoying if you keep the clock in a bedroom.
- Long tube life: The multiplexed display and automatic dimming used in this design extends the life of the tubes indefinitely. Other designs run the tubes too “hard”, and this causes a rapid degradation in the useful life of the tube.

General

The clock has different modes of operation, which you select using the pushbutton. When you start the clock up th very first time, it will start in “Time Display Mode”. We set it up to be the right time for where the clock is being shipped to, so in the best case you will not even need to set the clock the first time!

The other modes of operation are described in the following sections.

Safety

The voltages produced in the High Voltage circuit can reach peaks of 400V! Take precautions not to electrocute yourself! If you are not sure what this means, please do not use this clock and return it for a full refund.

A shock from the clock high voltage circuit is at least a nasty bite. At worst it can kill you.

We decline any responsibility in the case of injury or death.

REPEAT: If you are not sure, please do not use the clock.

Time Display Mode

Normally, the clock will show the time. To show additional information press the button with a “short” press. Each press cycles through the following information. After 5 seconds, the display will revert to the normal time display.

Mode	Description	Values
Date	**Date.** The current date will be shown.	
Temp	**Temperature.** The current internal temperature inside the clock case will be shown in degrees Celsius. If this goes above 40, you should consider ventilating the case, because the temperature compensation is not able to work at such high voltages, and the clock life may be reduced, and the time may drift.	
Light	**Ambient Light Reading.** This shows the current ambient light reading from the LDR (light dependent resistor). It is a normalized value, and goes between 100 (dark) to 999 (bright). This controls the dimming of the tubes.	100: dark 999: bright

the date, press the button with a “short” press. Press the button again with a “short” press to show the temperature.

Setting Mode

To enter setting mode, press the button for more than 1 second (“medium press”). The “tick” LED will start to flash instead of pulse. The number of consecutive flashes indicates the mode you are in.

Each medium press of more than 1 second will move the setting mode onto the next. When you finish the setting modes, the clock returns to normal time display mode.

To exit the setting mode before going through all the options, press the button for more than 2 seconds (“long press”). The “tick” LED will start to pulse again. Another way of exiting is to cycle through all of the setting options, after which you will return to time mode.

To change a setting, press the button for less than one second, and then release it (“short press”).

Mode	Description	Values
0	**Time mode.** This is the normal mode and displays the time. It is the normal start up mode of the clock. If you do nothing. The clock is in this mode. In this mode a short press cycles through the values given in “Time Display Mode”, but always returns to the standard time display after 5 seconds.	
1	**Set minutes.** Each short press will advance the minute. The minutes roll over back to 0 ffter reaching 59 minutes. Each time you set the minute, the seconds is reset to 0.	
2	**Set Hours.** Each short press will advance the hour. The hours roll over back to zero after reaching 12 or 24 (depending on the 12/24 hours mode).	
3	**Set Day.** Each short press will advance the day. The day roll over back to one after reaching the maximum number of days in the month.	
4	**Set Month.** Each short press will advance the month. The month roll over back to zero after reaching 12.	
5	**Set Year.** Each short press will advance the year. The year roll over back to 2015 after reaching 2099.	
6	**Fade Speed Slower**. Each short press will make the fade speed between digits slower.	Default: 50 Max: 200 Min: 20
7	**Fade Speed Faster**. Each short press will make the fade speed between digits faster.	Default: 50 Max: 200 Min: 20
8	**HV Generator Frequency Higher.** This controls the internal frequency of the HV generator. The lower the number, the higher the frequency of the HV generation. Normally you will not have to adjust this, but with some tubes, adjusting it can stop “flickering” in the filaments. Before leaving the clock for long periods with a new setting, check that IRF740 MOSFET is not running too hot.	Default: 200 Max: 400 Min: 100
9	**HV Generator Frequency Lower.** This controls the internal frequency of the HV generator. The higher the number, the lower the frequency of the HV generation. Normally you will not have to adjust this, but with some tubes, adjusting it can stop “flickering” in the filaments. Before leaving the clock for long periods with a new setting, check that IRF740 MOSFET is not running too hot.	Default: 200 Max: 400 Min: 100
10	**Scroll-back Speed Slower.** Each short press will make the “scroll-back” speed slower.	Default: 4 Max: 40 Min: 1
11	**Scroll-back Speed Faster.** Each short press will make the “scroll-back” speed faster.	Default: 4 Max: 40 Min: 1
12	**12 or 24 hour time.** The hours are displayed in 12 or 24 hour mode.	“1” = 12 hour “0” = 24 hour
13	**Blank leading “0”.** Blank out the leading “0” from single digit hours.	“1” = blank “0” = don't blank

14	**Scroll back.** Use the scroll back (rapid count down) effect when changing from “9” to “0”.	“1” = enable “0” = disable
15	**Red Channel Intensity.** Sets the maximum intensity of the red channel back light. This will be dimmed according to the display dimming.	Default: 255 Max: 255 Min: 0
16	**Green Channel Intensity.** Sets the maximum intensity of the green channel back light. This will be dimmed according to the display dimming.	Default: 255 Max: 255 Min: 0
17	**Blue Channel Intensity.** Sets the maximum intensity of the blue channel back light. This will be dimmed according to the display dimming.	Default: 255 Max: 255 Min: 0
18	**Current case temperature.** Show the current temperature inside the case (used as part of the temperature compensation for the clock crystal).	
19	**Clock version.** Show the clock software version. In this version, will show “0006”.	
20	**Digit Test.** Will roll through all digits on all locations to check that the display is healthy.	

Display Blanking Mode

During display blanking mode, the “tick” LED will continue to pulse at low intensity, telling you that the clock is still running. In order to display the time, just press the button, and the time will be displayed.

If you want to enable the display for the rest of the day, do a long press of the button.

Tube Healing Mode

After a long period of time, tube filaments which are not often used (e.g. the “9” on the tens of hours or minutes) can get dim, despite the ACP that is regularly done.

If you make a “super-long” press of the button (more than 8 seconds), the clock will enter filament healing mode. All the power will be placed through a single filament of a single digit to clean it. A short press will change the selected filament.

Another super-long press or cycling through all the filaments will return the clock to normal.

Caution! Don't leave a single filament in this state for an extended period of time. It is a harsh process, and may damage the tube if you leave it in this mode for too long. Normally a few minutes will restore the cathode digit.

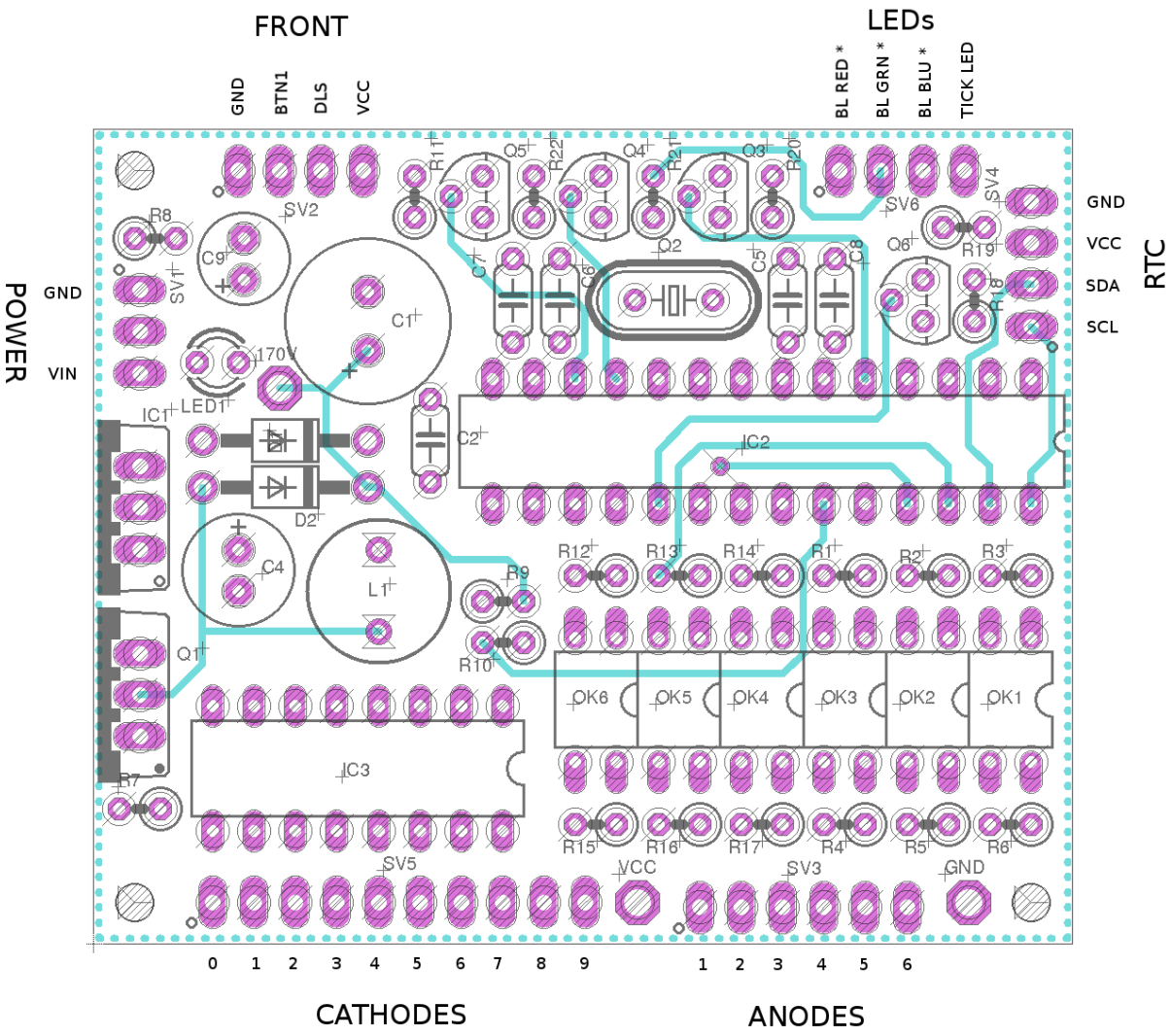
Factory Reset

To reset the clock back to initial settings, hold down the button while powering on and hold for at least 3 seconds. The “tick” LED will flash 10 times to signal that the reset has been done.

Everything will be reset back to the factory default state.

Board layout

For reference, the board layout is as shown (viewed from the top):



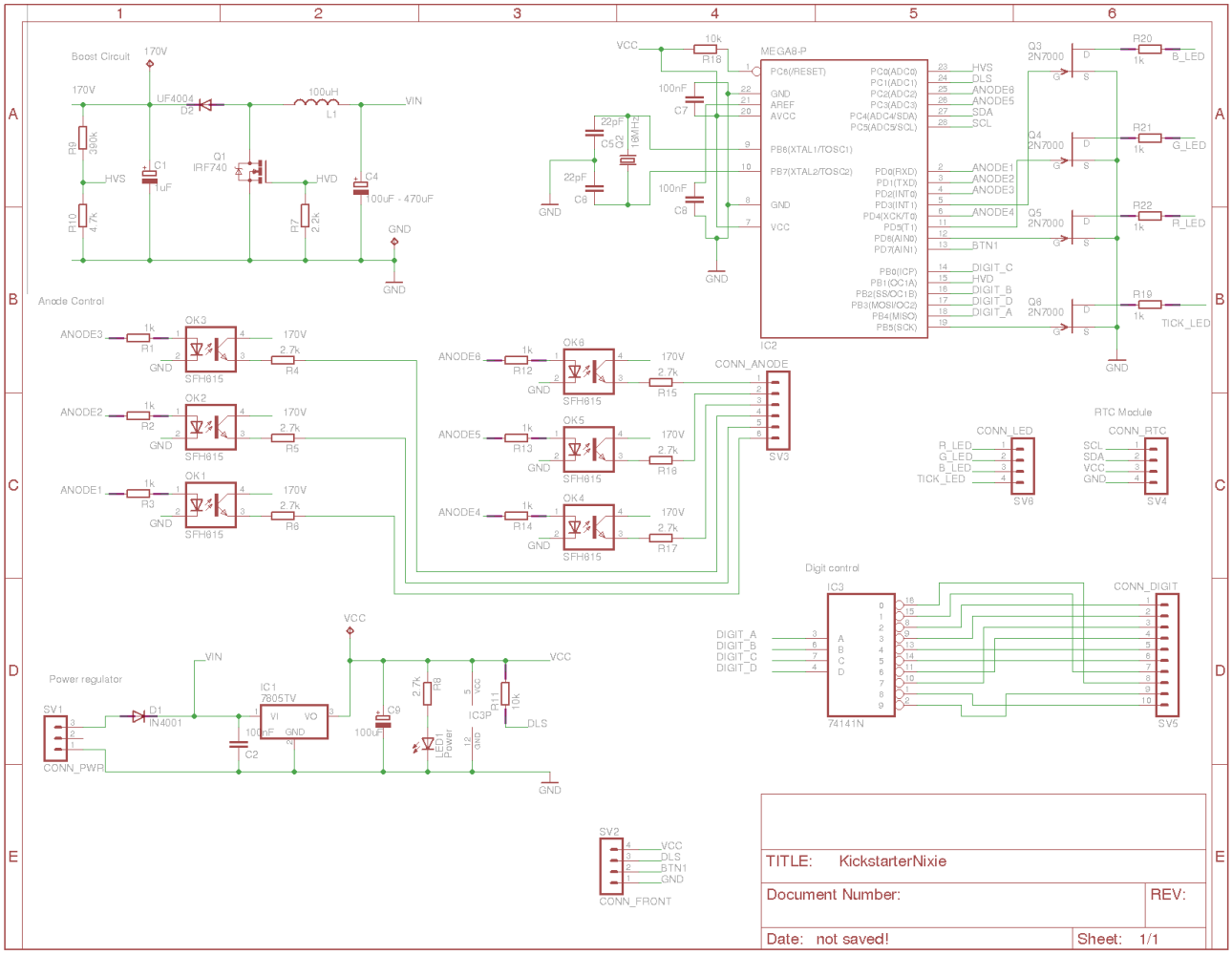
The connections are:

Connector	Description	Values
POWER	Power. External power should be applied to the board with this connector. Any DC input source is possible, from 7V – 12V. Higher voltages may be possible, but could cause the digits to flicker is the voltage is too high. The absolute maximum input voltage is 30V. Any higher voltage than this will damage the board! The input is protected against the input being connected reversed. The input current ranges from 300mA to 1A depending on the size of the tubes and the number of LEDs you are driving. **GND:** The negative side of the input supply	

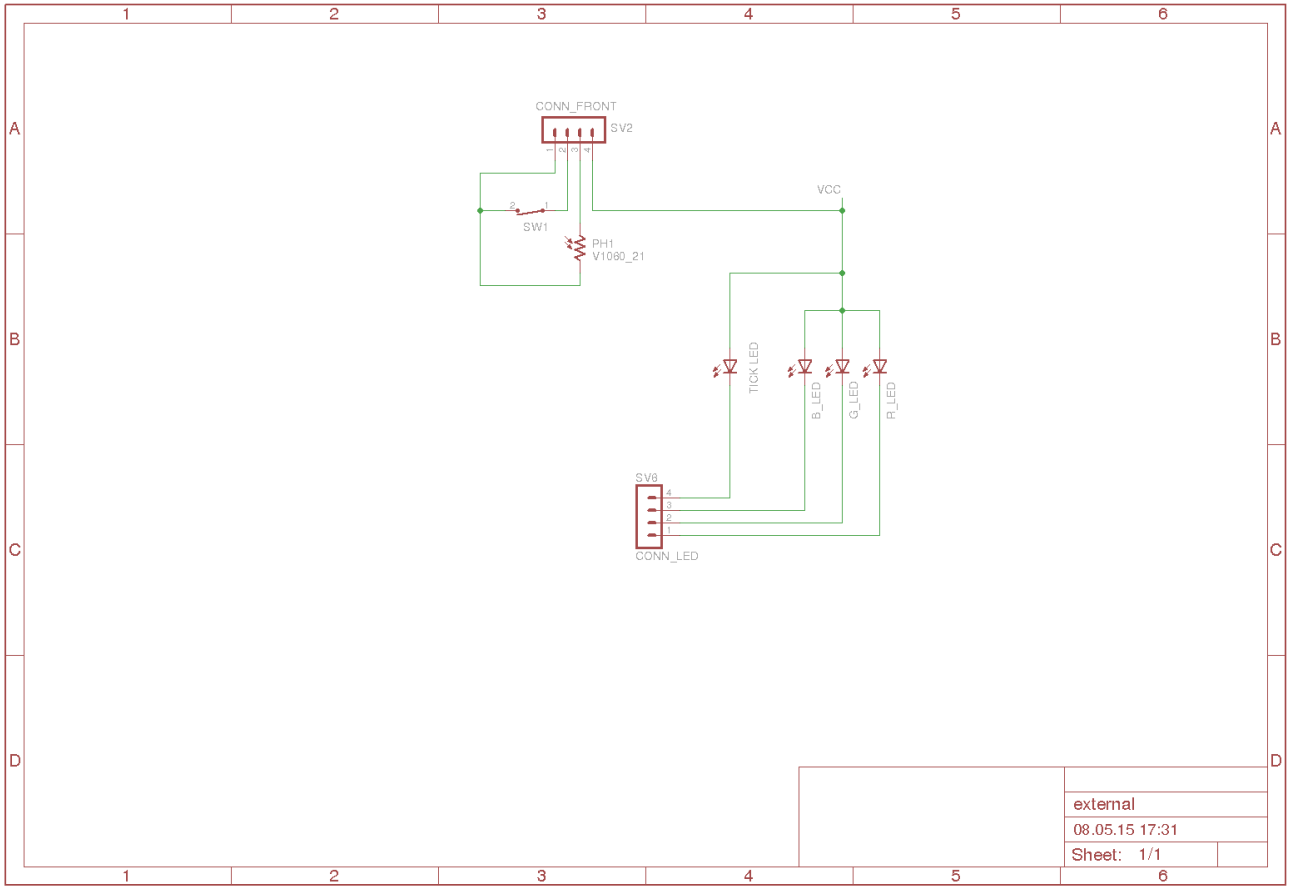
	VIN: The positive side of the input supply
FRONT	Front Panel. These are the controls that go on the front panel: The input button and the Light Dependent Resistor to detect ambient light. **GND:** The “ground”. One lead of the button and one lead of the LDR are connected to this. **BTN1:** The other lead of the button is connected to this input **DLS:** The other lead of the LDR is connected to this **VCC:** Regulated 5V output to drive any LEDs or lighting.
LEDs	The LEDs are connected to these sink terminals. To connect up you take the positive sides of the LEDs to either VIN or VCC and connect the negative sides of the LEDs to these termionals. **BL RED *:** PWM cathode connection for the back light RED channel. **BL GRN *:** PWM cathode connection for the back light GREEN channel. **BL BLU *:** PWM cathode connection for the back light BLUE channel. **TICK LED:** Cathode connection for the blinking “tick” LED.
RTC	The connection for the RTC (Real Time Clock) module. Connect this to the approriately marked terminals on the RTC module.
CATHODES	The terminals to the cathodes (individual digits “0” - “9”) for each tube.
ANODES	The terminals to the anodes for each tube.

Schematic

Below is the schematic for the clock.



And for the external components, showing how they are connected.

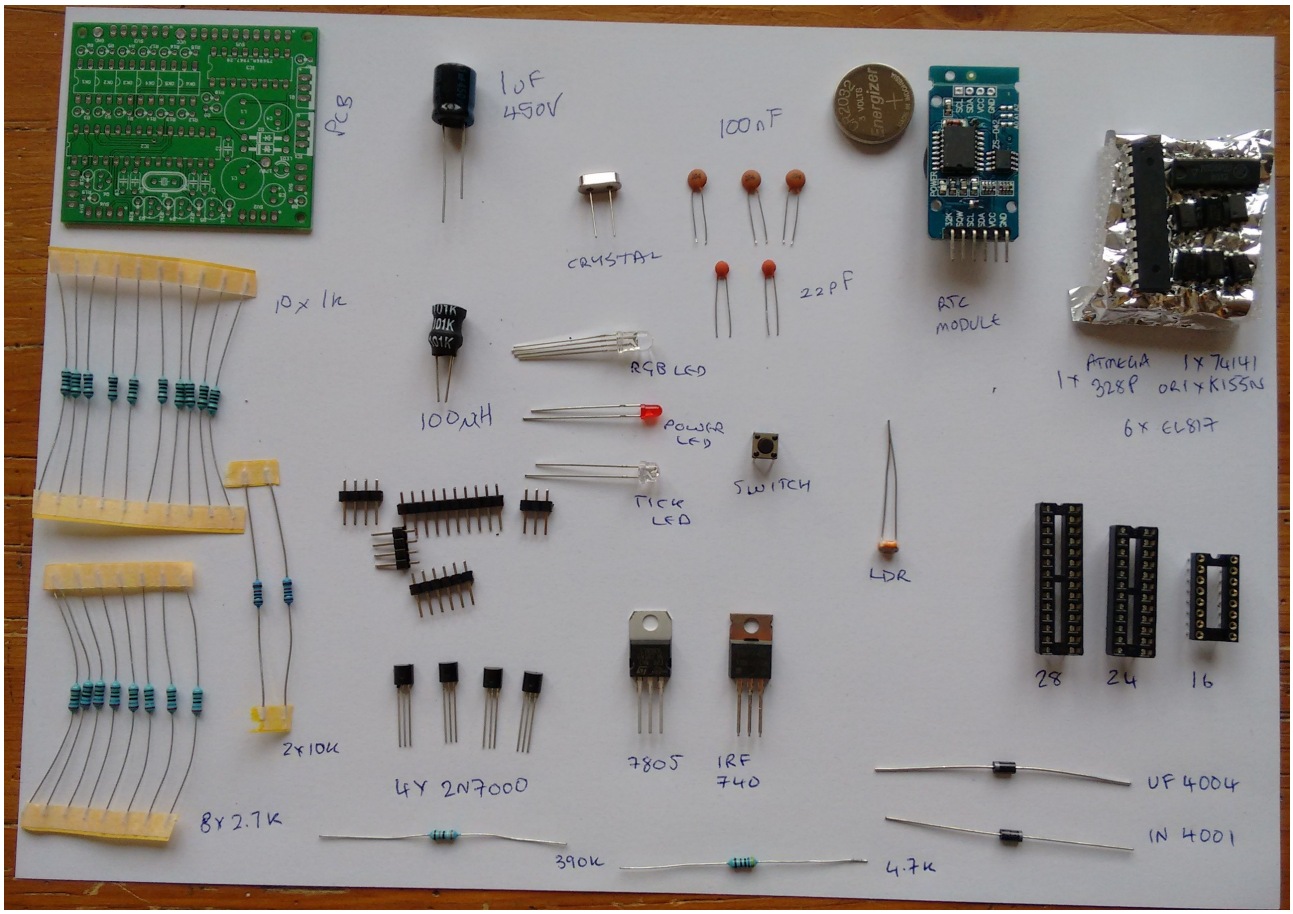


The LDR and switch are connected to ground (pin 1).
The LEDs are driven preferably from VCC (regulated 5V).

Construction

Kit Contents:

When you unpack the kit, you should find the following contents:



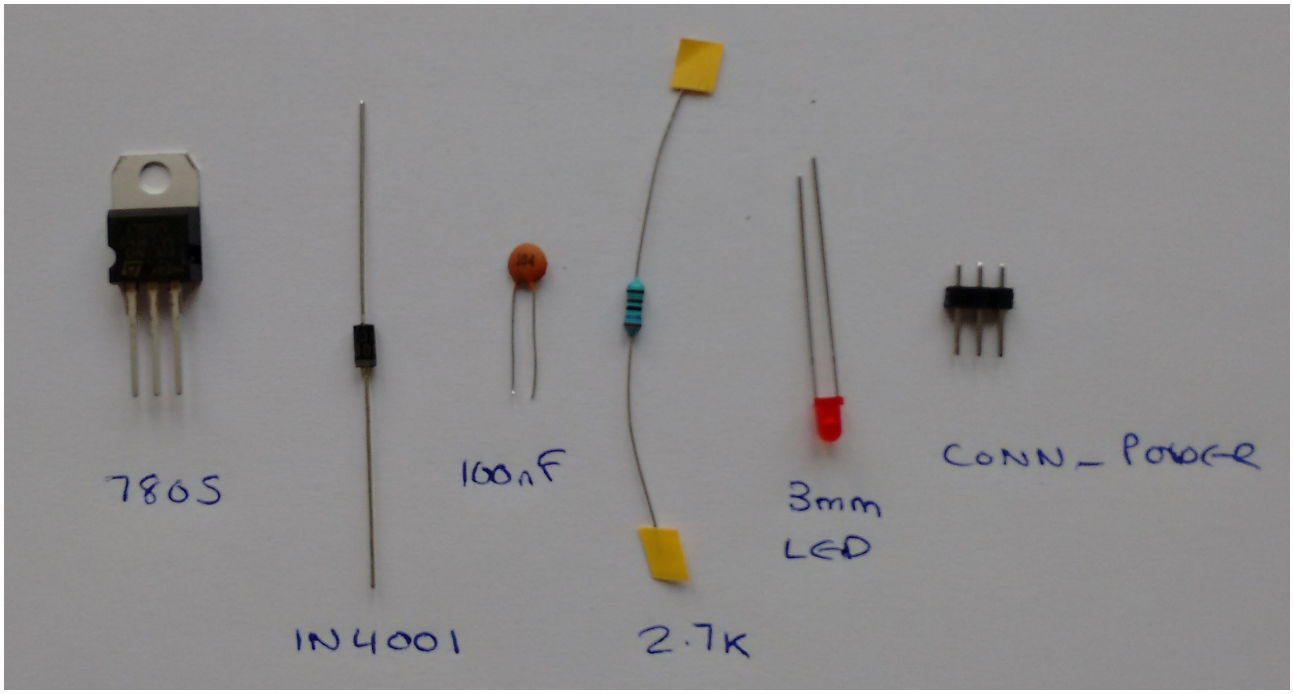
Low Voltage Circuit:

Parts List:

D1	IN4001
C2	100nF
IC1	7805TV
C9	100uF
R8	2.7k
LED1	LED3MM
SV1	CONN_POWER

The Low Voltage circuit is a very traditional voltage regulator using a linear regulator. It's job is to reduce the external voltage from the power adapter down to a known and stable 5V to drive the micro-controller.

Put the parts on the board in the marked locations in the order they appear on the list.



Notes:

- D1 and D2 look very similar, but have different jobs to do. Be careful to get the 1N4001 and not the UF4004.
- D1 should be placed so that the white stripe on the body lines up with the white stripe on the board.
- C9 must go the right way round. The negative side is marked with a stripe.
- The LED must go with the right polarity. The + side has a flat on it, and has the shorter lead.
- Put IC1 so that the metal tab lines up with the white stripe on the board. The metal side faces to the *outside* of the board.

Once all the components are on the board, hook up the power, and check that the LED comes on. Check also that the voltage is 5V between the “GND” test point and the “VCC” test point.

If the LED does not come on, turn off immediately to avoid damage to the components.

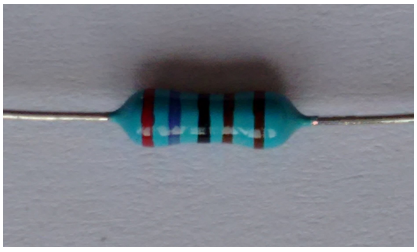
If all is well, proceed to the next step. If not, check carefully the orientation of the components and the power leads. Diode D1 protects the board from having the power connected inverted.

If the LED comes on, check for a few seconds that the 7805 does not heat up. It should stay almost cold.

Hint: The resistor color code 2.7k

The color code for the 2.7k resistor is:

RED = 2
VIOLET = 7
BLACK = 0
BROWN = 1 (1 zero in this case)
Brown = 1 (1% Tolerance)
= 2 7 0 0 with 1% tolerance



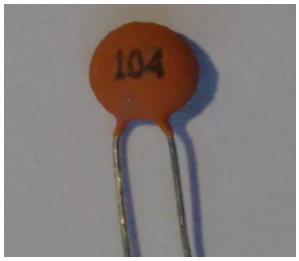
2.7k resistor

Hint: The 100 nF capacitor

The coding on the 100nF capactor is "104".

This is decoded as:

= "1" then a "0" and then 4 more zeros
= 100000 pF
= 100 nF (1 nF = 1000 pF)



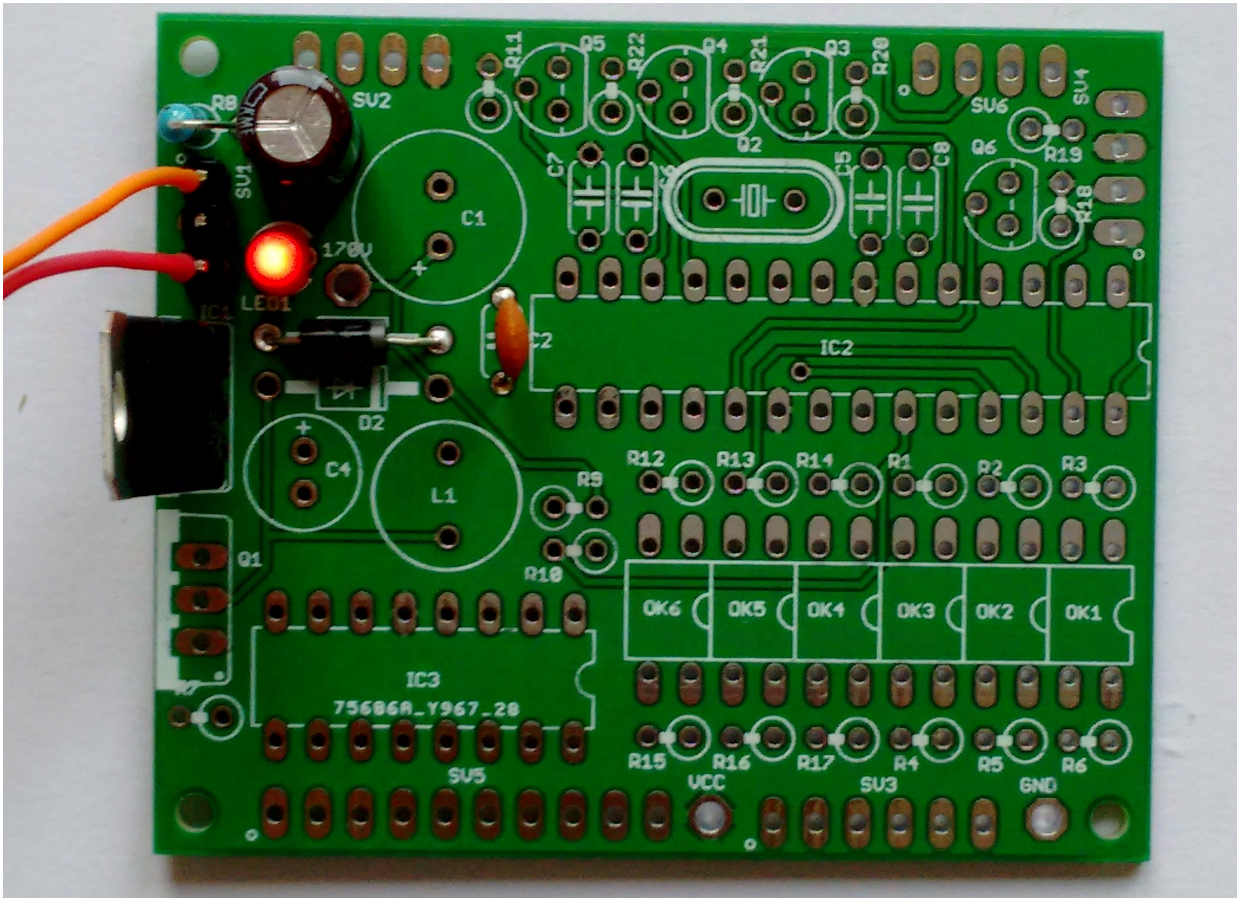
100nF capacitor

Hint: The 100 uF capacitor

The electrolytic capacitor has a stripe on it to denote the **negative** side of the capacitor. The positive side of the capacitor (which goes into the "+" on the board) is the other one!

100uF capacitor "stripe"

At the end of the low voltage circuit build, your board should look like this:



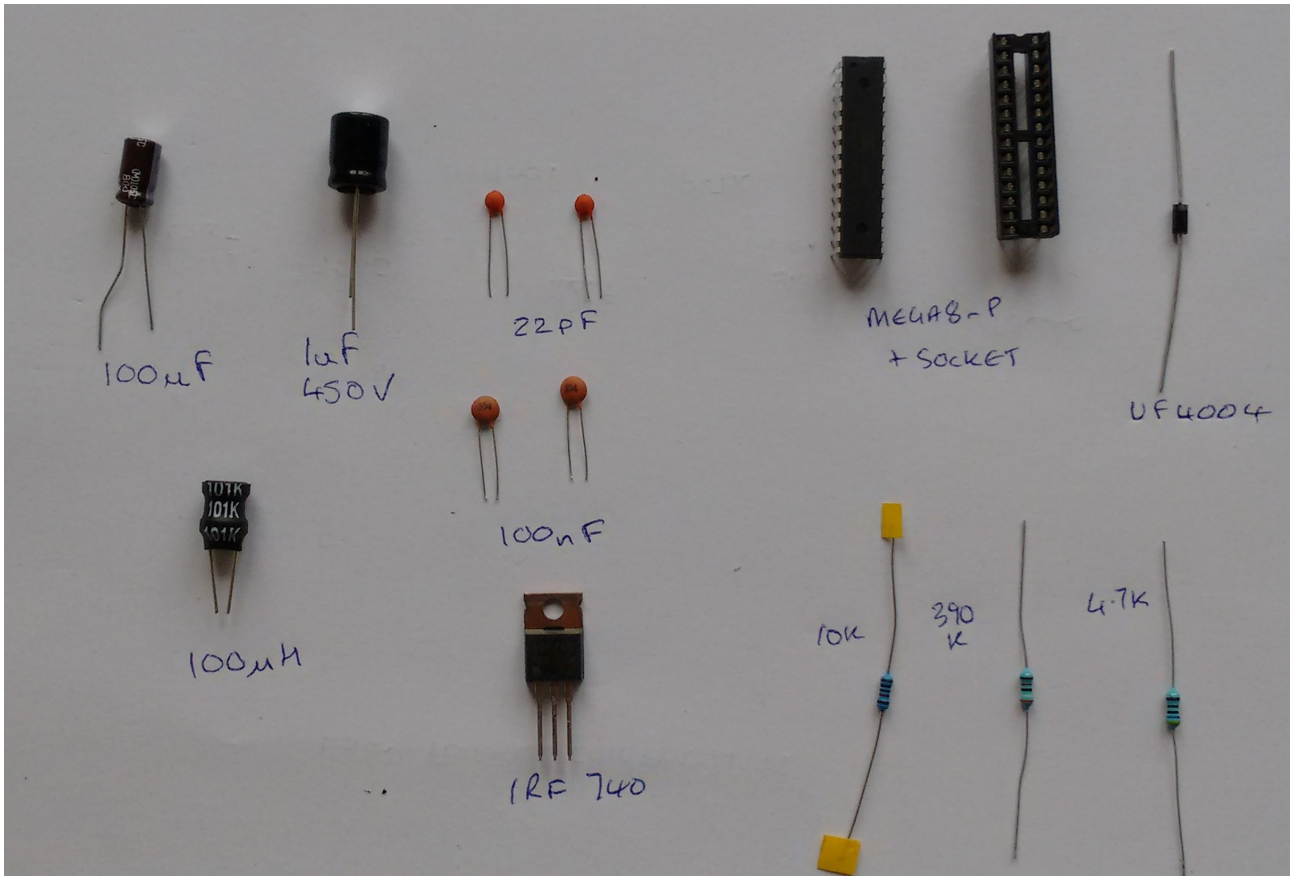
Low Voltage Circuit

High Voltage Circuit:

Parts List:

C5	22pF
C6	22pF
C1	1uF
C7	100nF
C8	100nF
C4	100uF - 470uF
D2	UF4004
IC2	MEGA8-P
Q2	16MHz
L1	100uH
S24	SOCKET 28
Q1	IRF740
R9	390k
R18	10k
R10	4.7k

The high voltage circuit uses the micro-controller to drive the boost circuit with a high frequency square wave, and has a feedback loop in which the controller reads the voltage produced via an analogue input, and regulates the brightness of the tubes so that there is no flickering or unwanted dimming.



Notes:

- C4 must go the right way round. The negative side is marked with a stripe (see hint).
- Put Q1 so that the metal portion lines up with the white stripe on the board. The metal side faces to the outside of the board.
- D2 should be placed so that the white stripe on the body lines up with the white stripe on the board.
- Put the micro-controller socket in first. Make sure that the depression on the end of the socket lines up with the marking on the board. When you put the chip in, the chip should go in with the depression faces to the outside of the board.
- C5 and C6 have "22" written on them, whereas C7 and C8 have "104" written on them (see hint)

Once all the components are on the board, hook up the power. **If you hear any angry sounding buzzing turn the power off immediately and check the orientation of C1!** The circuit should run almost silently.

Be careful, we are dealing with high voltages now! If all is well, measure the voltage at the "170V" test point. It is high voltage and the voltage may be significantly higher than 170V at the moment, because the high voltage generator is powerful and the output is not loaded. Once you add a load, (by connecting the tubes), the voltage should oscillate around 170V – 190V, and might have a slight "sawtooth" appearance.

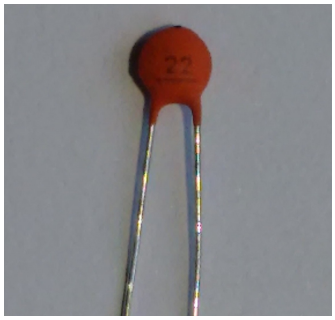
You can also check the voltage using an old neon lamp if you have one. Temporarily connect the neon lamp between the "GND" test point and the "170V" test point (turn the power off first). Turn the power on and the neon lamp should come on.

Q1 can get warm, but should not get hot. If it gets hot, you need to check the orientation of the components and that there are no solder bridges.

If you read a high voltage, proceed to the next step.

Hint: The 22 pF capacitor

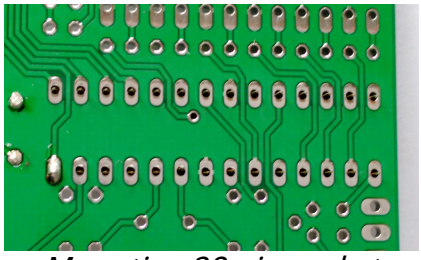
The coding on the 22pF capactor is simply "22". It does not matter which way round it goes.



22pF capacitor

Hint: Mounting the 28 pin socket

Mounting the 28 pin socket can be a little tricky. A good trick is to fix it in place with a small piece of tape, and the solder one leg in place. You can hold the socket firm while you "wet" the solder again. One leg is usually enough to hold the socket in place while you solder the others

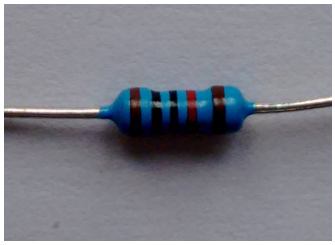


Mounting 28 pin socket

Hint: The 10 k resistor

The color code for the 10k resistor is:

BROWN = 1
BLACK = 0
BLACK = 0
RED = 2 (2 zeros in this case)
Brown = 1 (1% Tolerance)
= 1 0 0 0 0 with 1% tolerance

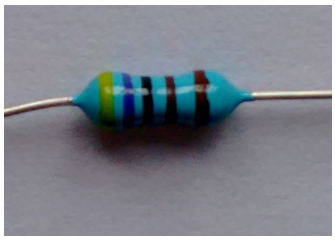


10k resistor

Hint: The 4.7 k resistor

The color code for the 4.7k resistor is:

YELLOW = 4
VIOLET = 7
BLACK = 0
BROWN = 1 (1 zero in this case)
Brown = 1 (1% Tolerance)
= 4 7 0 0 with 1% tolerance

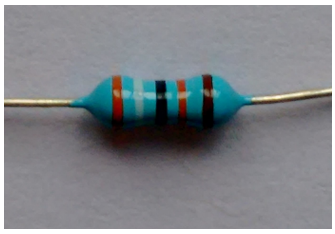


4.7k resistor

Hint: The 390 k resistor

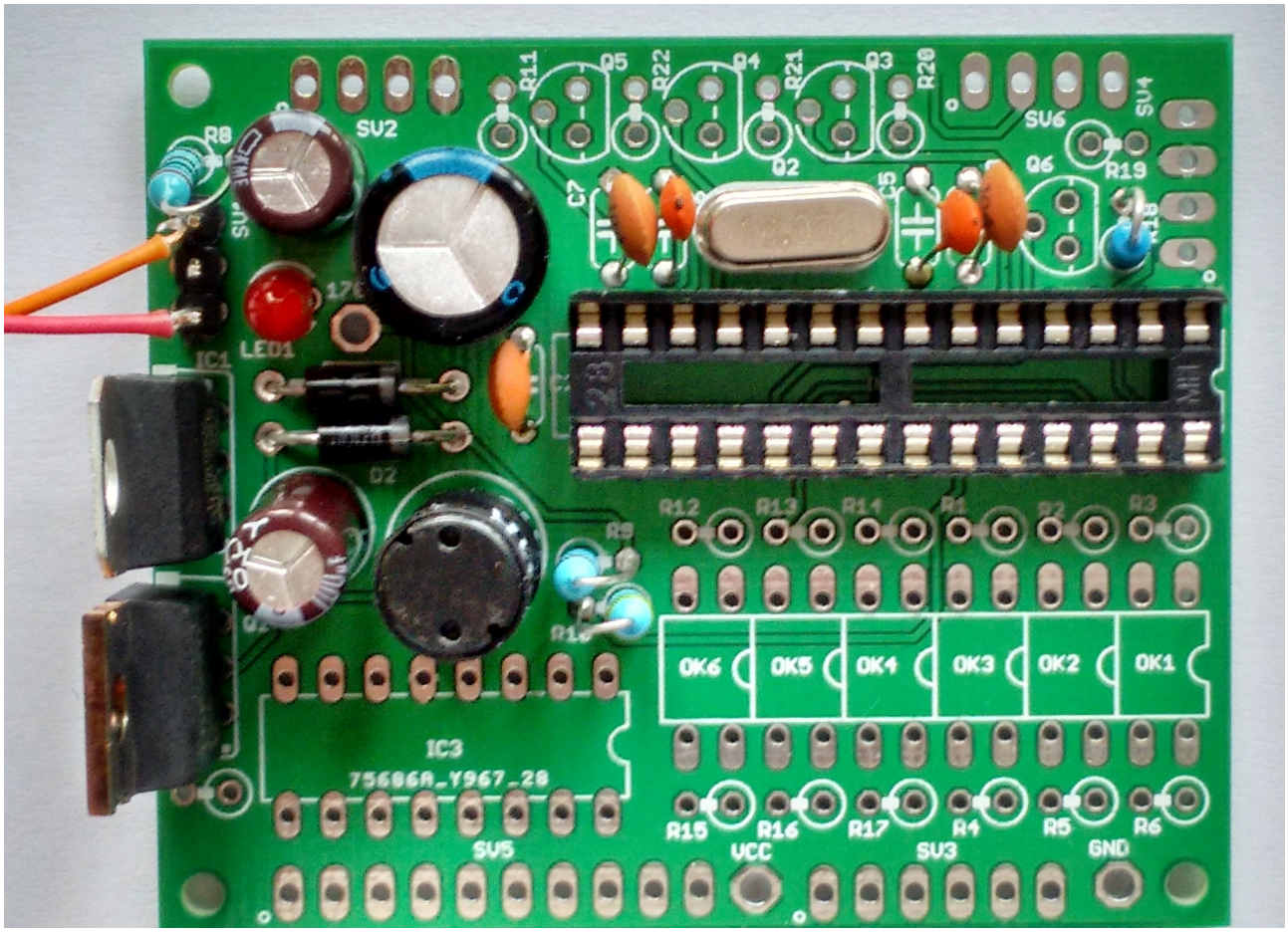
The color code for the 390k resistor is:

ORANGE = 3
WHITE = 9
BLACK = 0
ORANGE = 3 (3 zeros in this case)
Brown = 1 (1% Tolerance)
= 3 0 0 0 0 with 1% tolerance



390k resistor

At the end of the high voltage circuit build, your board should look like this:



High Voltage Circuit

“TICK LED” Circuit:

Parts List:

RTC	RTC
SV4	CONN_RTC
R19	1k
Q6	2N7000
TICK LED	LED 5mm
SV6	CONN_LED
SV2	CONN_FRONT

This step will check that the Micro-controller can talk to the RTC module, and that the time counting is working properly.

Notes:

- Q6 should be orientated with the flat side as shown on the board. Some FETs come with the leds in a row rather than in a triange. If this is the case, bend the middle lead slightly so that it fits the holes in the board (see hint).
- The RTC module has two sets of contacts on it. You can use either the side with the pins on it or wire up the other side with flying wires. If you use the side with pins, you should carefully remove the two unused pins (see hint).
- The LED must go with the right polarity. The + side has a flat on it, and has the shorter lead (see hint).

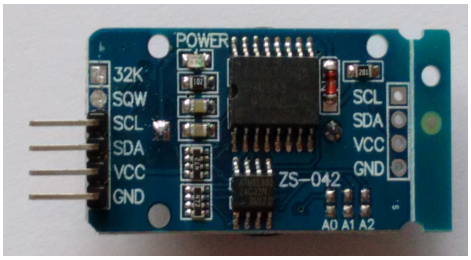
The LED should be wired up with the longer lead to pin 4 of the CONN_FRONT (SV2) connector and the shorter lead to pin 4 of the CONN_LED (SV3) connector.

Once you have populated the components, power on. The TICK LED should flash on and off slowly (on for 1 second, off for one second).

Hint: Trimming the extra pins on the RTC module

ONLY if you want to mount the RTC module directly onto the main board (you can also do it via flying leads), trim off the pins “32K” and “SQW” using a pair of precision side cutters.

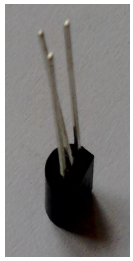
If you want to mount using flying leads, you can skip this step.



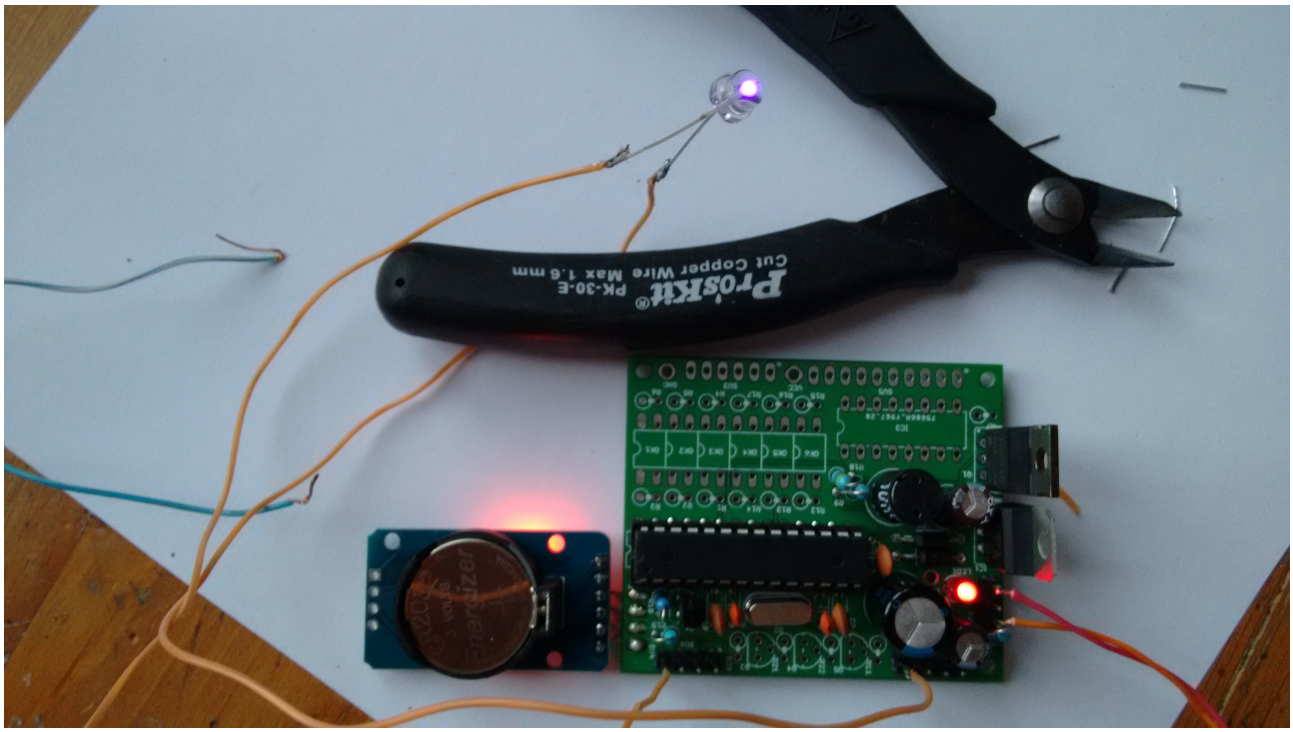
RTC Module with pins removed

Hint: 2N7000 mounting

To mount the 2N7000 FET, bend the middle lead back slightly. It will then fit in the PCB without problems.


2N7000

After you have wired everything up, it should look like this:



Note that here I have put the RTC module directly onto the main board. The battery goes in the RTC module with the back upwards.

Anode Control Circuit:

Parts List:

OK1	EL817
OK2	EL817
OK3	EL817
OK4	EL817
OK5	EL817
OK6	EL817
R1	1k
R2	1k
R3	1k
R12	1k
R13	1k
R14	1k
R4	2.7k
R5	2.7k
R6	2.7k
R15	2.7k
R16	2.7k
R17	2.7k
S24	SOCKET 24
SV3	CONN_ANODE

This circuit controls passing the HV to the anodes of the tubes. The micro-controller multiplexes the anodes by turning each of them on it turn.

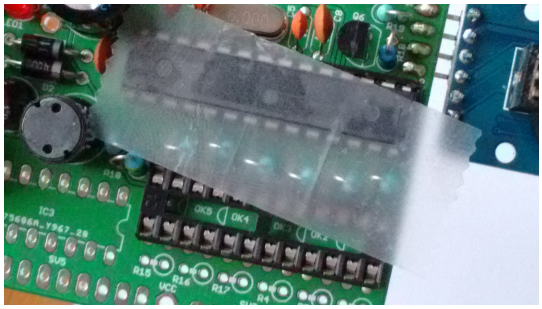
Notes:

- The Opto-Isolators fit into the 24 pin socket snugly. Be careful to put them in the right way round. The dot denotes pin 1 and should be on the side closest to the micro-controller. All 6 should fit perfectly into the 24 pin socket.
- The Opto-Isolators are socketed because they are sensitive to heat and are easily destroyed if you apply too much heat to them. Putting them in a socket means that we don't run the risk of destroying them.

Hint: Putting the resistors in

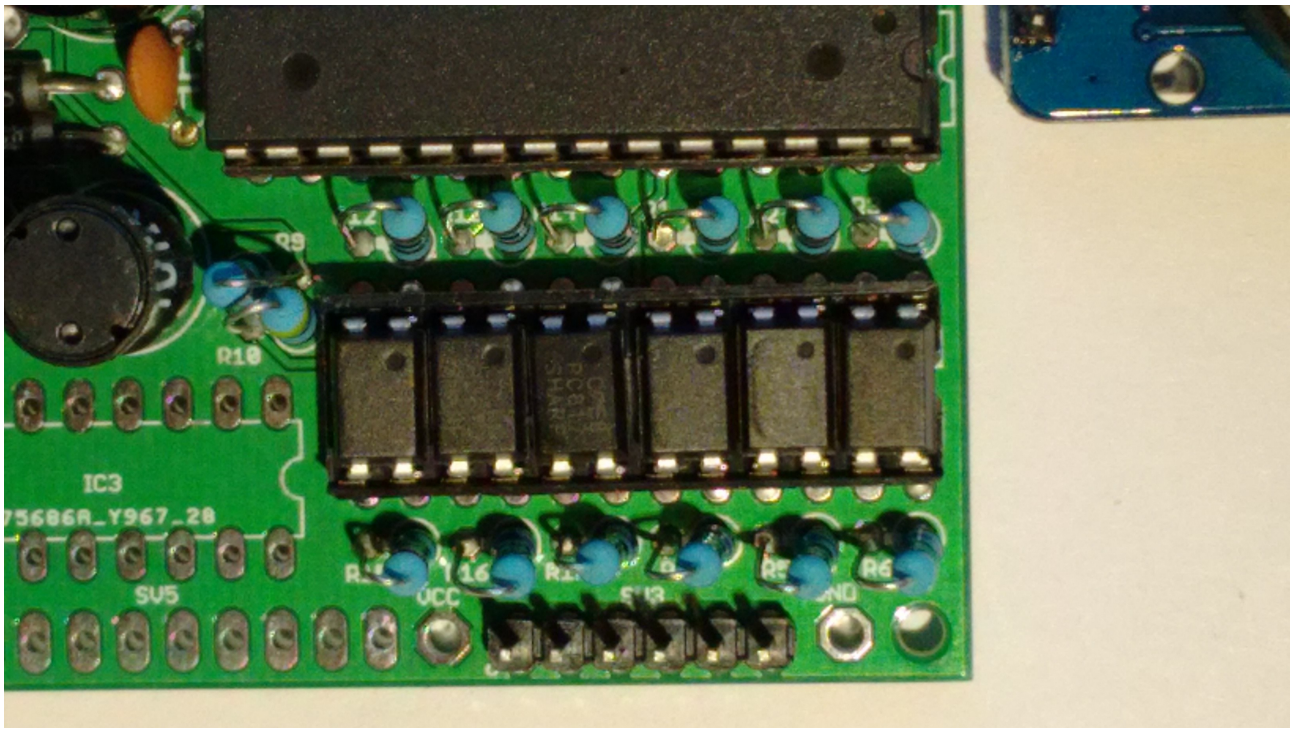
A trick that can speed assembly up is to use a piece of normal sticky tape to hold things in place while you solder them. This makes is easier to solder and gives a better result.

Place the components, and then temporarily tape them into place.



Using tape to hold resistors in place

After you have installed the Anode controls, that part of the board should look this:



Cathode Control Circuit:

Parts List:

IC3	74141N
S16	SOCKET 16
SV5	CONN_DIGIT

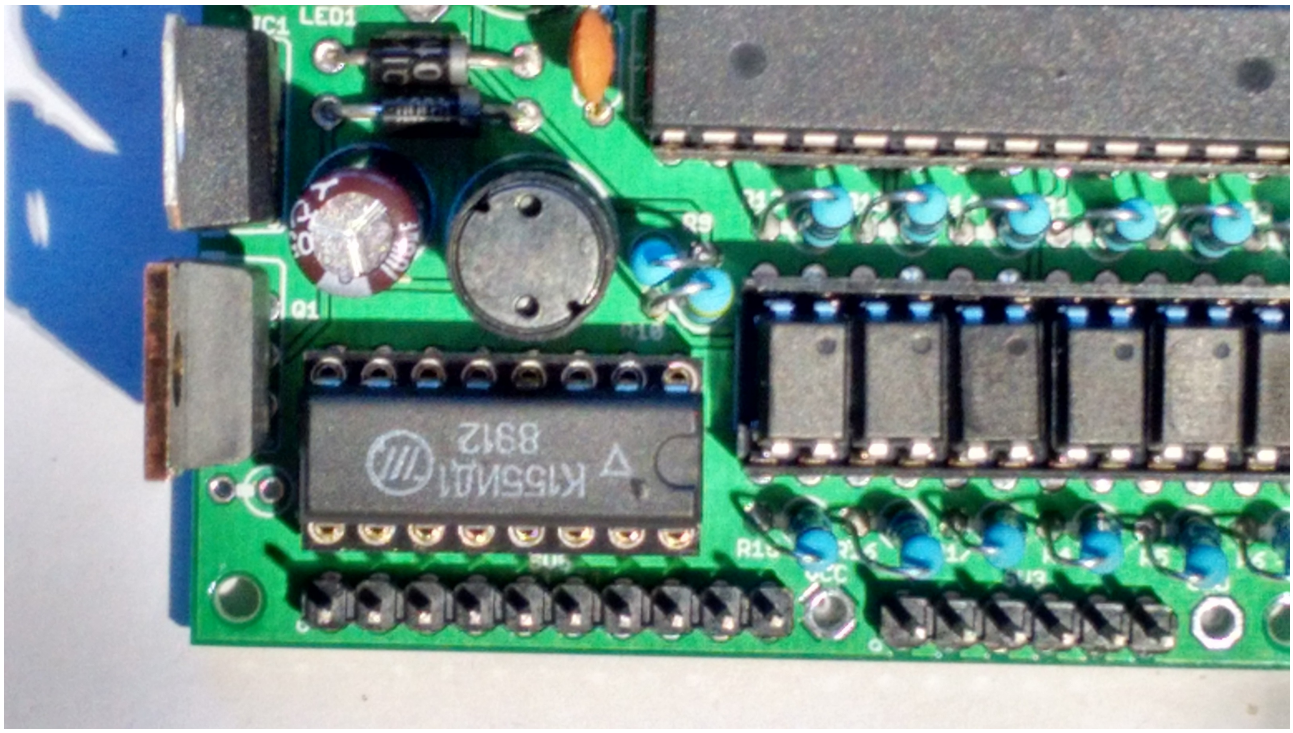
This part of the circuit controls which cathode will be lit. Each time the digit to be displayed, the correct cathodes have to be set.

Notes:

- Instead of the 74141, you might have the Russian equivalent “K155”.
- Be careful to orient the 74141 correctly

Place the 16 pin socket and the connector, and then put the cathode driver on the board.

After you have done this, that part of the board should look like this:



LEDs and front panel

Parts List:

R20	1k (*)
R21	1k (*)
R22	1k (*)
Q3	2N7000
Q4	2N7000
Q5	2N7000
R11	10k
LDR	LDR
S1	SWITCH
LED RGB	LED RGB

These are the final parts of the clock apart from the tubes, and are intended as the elements which the user sees and touches.

This is the last step of the main board build.

Notes:

- The FETs should be orientated with the flat side as shown on the board. Some FETs come with the leds in a row rather than in a triange. If this is the case, bend the middle lead slightly so that it fits the holes in the board (see hint).
- If you want to run more than one back light LED from the board, see the note below.

(*) You can run more than one back light LED for each R,G or B channel. If you want to do this, replace this resistor with a simple PCB link, and put a 1k resistor in series with each LED cathode instead. You can run between 4 and 6 LEDs off the driver depending on the type and the supply (you can choose the regulated 5V or the unregulated VIN). The total current for each channel should not exceed 200mA.

To calculate the current drawn, you can measure the forward drop V_{FWD} across the LED when it is on, and use the following formula to calculate the current:

$$I_{LED} = V_{CC} - V_{FWD} / 1k$$

For example, with a V_{FWD} of 2.2V, the current is:

$$I_{LED} = 5 – 2.2 / 1k = 2.8mA$$

In this case, you can safely run 6 LEDs off the channel.

When all the components are installed, you are finished with the board.

The switch connects to ground when closed. It uses the internal pull-up resistor provided by the Atmega on the input pin to pull the input to VCC when the switch is not closed.

The switch is de-bounced in software, so practically any switch you want to use is suitable. A simple switch is provided in the kit, but you might want to substitute this switch with one that suits you case.

Connecting the tubes

When all the components are installed, you are now ready to install the tubes. Either you can wire then by hand or you have a board to put them on. I prefer hand wiring, because I think it has a more “retro” feel.

The anodes are arranged like this:

Anode “1”	Hours 10s
Anode “2”	Hours
Anode “3”	Minutes 10s
Anode “4”	Minutes
Anode “5”	Seconds 10s
Anode “6”	Seconds

Anode “1” is the one next to the tiny “o” on the board connector.

The cathodes are arranged like this:

Cathode “0”	Digit 0
Cathode “1”	Digit 1
Cathode “2”	Digit 2
Cathode “3”	Digit 3
Cathode “4”	Digit 4
Cathode “5”	Digit 5
Cathode “6”	Digit 6
Cathode “7”	Digit 7
Cathode “8”	Digit 8
Cathode “9”	Digit 9

Cathode “0” is next to the tiny “o” on the board connector.

Side note: There are some tricks in the software to make the wiring and the PCB easy and logical. We use a translation table in the software, and cross some of the standard channels to make the PCB more logical. You can also see this on the “digit control” section of the schematic. This means that we are not using the 74141 “0” output to drive digit “0”, but instead we are using digit “2” of the 74141 to drive digit “0”.

In the code (available on GitHub), we see this:

```
// Used for special mappings of the 74141 -> digit (wiring aid)
// allows the board wiring to be much simpler<
int decodeDigit[16] = {2,3,7,6,4,5,1,0,9,8,10,10,10,10,10,10};
```

When we come in with a “0”, we decode this to “2” (the 0th element of the array), and in fact, it is the “2” output that is activated, but the wiring brings the “2” output to the “0” connection.

The cathodes to the tubes (the digits for each tube) need to be wired in parallel, “daisy chaining” them, so that the run to the same digit of each tube.

The anodes run exactly one tube each.

The wiring for the tubes is this: